
Performance and limitations of positron emission tomography (PET) scanners for imaging very low activity sources.

Journal: Phys Med

Publication Year: 2013

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PubMed link: 23680361

Funding Grants: In Vivo Imaging for the Detection and Quantitation of Transplanted Stem/Progenitor Cells in Nonhuman Primates

Public Summary:

These studies assessed Positron Emission Tomography (PET) scanner performance for use in stem cell trafficking studies. This is a regime in which PET scanners are not normally used, but is highly relevant to the application of longitudinal monitoring of radiolabeled stem cells via PET imaging post-transplantation, where cells are labeled ex vivo with tracer amounts of ^{64}Cu or ^{89}Zr and then administered and imaged in vivo. The goal was to determine how to optimize PET scanner design and operational parameters for such studies. We compared the counting rate performance for two clinical PET scanners using a modified National Electrical Manufacturers Association (NEMA) NU 2-2007 counting rate measurement as radioactivity concentrations decayed. The preclinical microPET scanner was also evaluated in this context. We hypothesized that the scanners based on lutetium oxyorthosilicate (LSO) would exhibit worse performance at these very low activity concentrations due to the contributions of events from the natural background radioactivity from the isotope Lu-176 present in the LSO detector material. In terms of counting rate performance, noise-equivalent count rate, and sinogram contrast-to-noise ratio they were found to be between 2 and 30 times greater suggesting that bismuth germanate-based scanners are far superior for detection and imaging of low activity levels that would be found in stem cell trafficking experiments.

Scientific Abstract:

Emerging applications for positron emission tomography (PET) may require the ability to image very low activity source distributions in the body. The performance of clinical PET scanners in the regime where activity in the field of view is $<1\text{ MBq}$ has not previously been explored. In this study, we compared the counting rate performance of two clinical PET/CT scanners, the Siemens Biograph Reveal 16 scanner which is based on lutetium oxyorthosilicate (LSO) detectors and the GE Discovery-ST scanner which is based on bismuth germanate (BGO) detectors using a modified National Electrical Manufacturers Association (NEMA) NU 2-2007 protocol. Across the activity range studied (2-100 kBq/mL in a 5.5 mL line source in the NEMA scatter phantom), the BGO-based scanner significantly outperformed the LSO-based scanner. This was largely due to the effect of background counts emanating from naturally occurring but radioactive ^{176}Lu within the LSO detector material, which dominates the observed counting rate at the lowest activities. Increasing the lower energy threshold from 350 keV to 425 keV in an attempt to reduce this background did not significantly improve the measured NECR performance. The measured singles rate due to ^{176}Lu emissions within the scanner energy window was also found to be dependent on temperature, and to be affected by the operation of the CT component, making approaches to correct or compensate for the background more challenging. We conclude that for PET studies in a very low activity range, BGO-based scanners are likely to have better performance because of the lack of significant background.

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